

# NAVAL POSTGRADUATE SCHOOL MONTEREY, CALIFORNIA



## THESIS

### COMPUTER MODELING AND SIMULATION OVERVIEW FOR A NAVY LOGISTCIAN

by

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June, 1996

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**COMPUTER MODELING AND SIMULATION OVERVIEW  
FOR A NAVY LOGISTICIAN**

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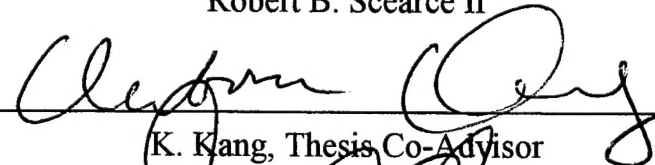
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## **ABSTRACT**

This thesis is intended to provide a Navy Logistician with an overview of computer modeling and simulation uses and management within the Department of the Navy. This thesis research indicates a large demand for models and simulations with joint applicability. It also indicates the need for the Navy to examine modeling and simulation management and organization to ensure economic and effective utilization. With decreasing Department of Defense budgets, the efficient management of this critical resource and capability is extremely important. The information contained in this thesis will be of value for a Navy logistician in providing knowledge about a few models and simulations and the trend towards joint applicability.



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## **I. INTRODUCTION**

### **A. BACKGROUND**

Simulation is one of the most frequently used system analysis methods. There are a number of reasons for this. First, simulation can be used to analyze models of arbitrary complexity. The complexity of the model is limited only by the ability of the modeler and the methodology to represent the system's complexity, and the computer's capacity to load and run the simulation program. The investigator's primary interest might be to experiment with the system model in order to find the design that maximizes one or more performance measures, or simply to study the behavior of the system. Experimenting with the real system is often out of the question because of the cost to implement system changes, or the potential danger that could result from some policies being tested. Often the modeling effort is useful in itself. The process of model development requires the system to be studied and understood well. This study frequently uncovers problems that were unknown or not understood before. Relative to other methodologies, simulation can carry more credibility with decision makers. For example, an animation, which is a visual representation of the model, can be used to demonstrate that the model actually approximates system performance. Thus, a simulation feels more "real" than other methods for system analysis. (Alexopoulos et al., 1995)

Computer modeling and simulation continues to take on increased use and focus in the Department of Defense (DoD). But now with reducing force levels and increasingly tight fiscal constraints the payoff of computer modeling and simulation is being seriously scrutinized. On June 1991 the Defense Modeling and Simulation Office (DMSO) was established by the Undersecretary of Defense for Acquisition. In addition to the promulgation of modeling and simulation policy, DMSO was to promote cooperation among DoD components in order to maximize efficiency and effectiveness. (MSIS, 1995, web)

However, it appears that a degree of dissatisfaction with the management of computer modeling and simulation exists within the DoD. Specifically, Pentagon officials cut funding for the DMSO about \$11 million to a level of about \$52 million. Funds could

have been cut to as low as \$40 million. While no programs were canceled "in-depth reviews of all priorities are continuing". A defense source stated, "we need to go back and look at all simulation priorities." (Holzer, 1996, p.16)

While the DoD is cutting funding to the main computer modeling and simulation office, the individual military departments are preparing for possible congressional budget attacks. Army Chief of Staff Gen. Dennis Reimer has initiated a complete internal review of modeling and simulation funding. The Army allocates almost two percent of its discretionary funding to computer modeling and simulation. This computes to about \$710 million for fiscal year 1997. "However simulation costs are rising and the Army is still asking for the same levels of OPTEMPO funding today as we have in the past." Gen. Reimer believes that Congress will find fault with the Army's investment efforts and that justification to Congress will be difficult. This will result more than likely in a reduction in funding. (Sherman, 1995)

Before we go any further, we must define a model and a simulation. A model is a representation of a system or process. A simulation is the implementation of a model over time. For the logistician, the most widely used model among all the military services is the level-of-repair analysis (LORA). With more emphasis on joint operations and joint acquisitions programs, such as the Joint Strike Fighter Program (JSF), it is important that a Navy logistician understand the level of repair analysis models of our sister services.

Each service has its own variation of LORA. The Army now uses the Computerized Optimization Model for Predicting and Analyzing Support Structures (COMPASS). This model replaced the optimum supply and maintenance model (OSAMM). The Navy uses the Level Of Repair Analysis (LORA) model and the Air Force uses the Network Repair Level Analysis (NRLA) model. As a Navy logistician it is important to understand the similarities and differences of these models.

## **B. FOCUS OF THESIS**

In this thesis, we will focus on computer modeling and simulation uses within the DoD. This is a highly complex problem that is gaining increased budgetary focus. We will concentrate on some uses of computer modeling and simulation in the DoD. We will study DMSO and also an overview of the modeling and simulation structure of the Navy. Then we will look at other Navy computer modeling and simulation logistics issues, including a joint program within DoD and investigate whether the management organization can be applied to computer modeling and simulation.

## **C. STRUCTURE OF THESIS**

Chapter II provides an overview of the variations of LORA used by each military service. Chapter III provides an overview of the Defense Modeling and Simulation Office (DMSO). It explores the organization, goals and future of the office. Additionally, this chapter provides an overview of the modeling and simulation management structure of the Navy. Chapter IV looks at a couple of issues within the Department of the Navy with regard to computer modeling and simulation. Chapter V highlights a few computer models in the area of joint logistics. Chapter VI provides the summary, conclusions and recommendations.



## **II. LEVEL OF REPAIR ANALYSIS (LORA) MODELS**

The purpose of this chapter is to examine LORA models being used by the different services. To perform the function of level of repair analysis, the Army, Air Force, and the Navy each uses a computer based, mathematical level of repair model. With decreasing defense budgets, it is highly likely that in a joint program, one would come into contact with a model from one of the other services. It is very important for military logisticians to be familiar with the similarities and differences of these math models.

### **A. U.S. ARMY: COMPUTERIZED OPTIMIZATION MODEL FOR PREDICTING AND ANALYZING SUPPORT STRUCTURES (COMPASS)**

#### **1. Background**

The development of COMPASS can be traced back to 1987. "The concept for developing COMPASS was originally conceived by a LORA subgroup at the LSA Technical Working Group (TWG) Meeting Number 6, 9-13 Feb 87. During this meeting, the subgroup determined models that were being used by the Army community for conducting LORA did not satisfy their needs." (USAMC, 1994) Thus a new program was initiated to design and develop a new math model. COMPASS was this new math model, with an initial goal of completion of between 3 and 10 years. The mathematical equations used in Optimum Supply and Maintenance Model (OSAMM) were used as the "basis in the development of COMPASS." (USAMC, 1994) COMPASS's purpose was to conduct system-level LORA previously conducted by OSAMM and Logistics Analysis Model (LOGAM) and to operate on a personal computer (pc) vice a mainframe computer. Given the technological advances in computer's, the result would be a program just as if not more powerful than its predecessors.

## **2. Model Overview**

### **a. COMPASS Products**

- "Repair level decision for each item under analysis."
- "Cost and allocation of manpower and support equipment required to repair the system."
- "Is it economical to develop test program sets (TPS)?"
- "Is it economical to screen an item before it is evacuated to another maintenance echelon for repair?"
- "Cost of initial and replenishment spares over the life of the system."
- "Overall costs associated with transportation, cataloging, training, technical manuals, etc."
- "Design for discard candidates."
- "Source for development of the MAC and Source, Maintenance, and Recoverability (SMR) code." (USAMC, 1994)

### **b. Model Highlights**

- "Maintenance concept decisions are made within COMPASS by considering all maintenance and supply related functions concurrently."
- Supply algorithms used in COMPASS have been taken from the Selected Essential-Item Stockage Availability Method (SESAME)
- "In order to determine the least cost maintenance alternative for each item, COMPASS formulates the problem in a linear programming form."
- If a user identifies an item in the input file, COMPASS will determine "the most economical location where the item should be removed and replaced, repaired or discarded."



- The user identifies the manpower and support equipment required to repair the items. COMPASS determines the optimal location for the manpower and support equipment.
- The user identifies lowest echelon where the repair equipment and repairperson is authorized and the lowest echelon where they are common. COMPASS computes the charges.
- "Cost elements within COMPASS are a mixture of one time and annual recurring cost."
- COMPASS determines the most economical location of repair (government or contractor)
- COMPASS considers basically 6 maintenance locations:
  - organizational (org)
  - direct support (ds)
  - general support (gs)
  - depot
  - contractor
  - discard

### **c. Model Outputs**

After the user has completed the building of the data file, there are three choices for execution. They are front-end analysis, optimizer, and evaluator. "The front-end analysis program should always be run before the optimizer or evaluator are run." (USAMC, 1994) The front-end analysis program identifies all errors in the input file and can also provide the user with a copy of all the data contained in the file. The optimizer and the evaluator will not run if there are any errors present. The optimizer program determines "the optimum (least cost) maintenance concept for the weapon system." (USAMC, 1994) The program will provide the optimum maintenance concept for each item the user listed in

the input file. It will also include the computation for life cycle and support cost for the maintenance concept that was selected. The evaluator program is "used to determine maintenance and support costs based on a user-defined maintenance concept." (USAMC, 1994) The user runs this program to conduct sensitivity analysis and to determine the effect on life cycle costs if a maintenance concept is changed or modified.

## **B. U.S. AIR FORCE: NETWORK REPAIR LEVEL ANALYSIS MODEL (NRLA)**

### **1. Model Highlights**

- "NRLA is the preferred means of performing LORA." It performs LORA for line replaceable units (LRU) and shop replaceable units (SRU) (ASC/ALTD, 1995)
- The model does not include all life cycle cost elements. It only includes those that have a direct impact on repair level decisions. Therefore, it is not a comprehensive life cycle cost model.
- The model chooses between three levels of repair: intermediate level repair, depot level repair, and discard -at-failure.
- The model does not attempt to allocate support equipment costs to individual items.

### **2. Model Assumptions**

- "The logistics system is composed of some number of operational locations (bases) and some number of centralized repair facilities (depots) supporting the bases." (ASC/ALTD, 1995) The base has two repair facilities, flight line and base shop (intermediate). The model assumes all bases send repairables to the same depot. Therefore the model assumes only one depot.
- "Intermediate level maintenance systems data (available work time per man, labor rate, and turnover rate) are assumed equal for all intermediate locations and all types of repair tasks." (ASC/ALTD, 1995)

- "Supply system data factors are assumed to be constant for all LRU's and SRU's being analyzed." (ASC/ALTD, 1995)
- "Only one set of technical data is purchased from the contractor." (ASC/ALTD, 1995)
- "Scheduled maintenance actions are not specifically considered by the model." (ASC/ALTD, 1995)
- "The model explicitly evaluates each LRU failure mode for a repair level decision." (ASC/ALTD, 1995)
- The model only evaluates the principal SRU for repair level decisions.
- The depot stock of SRU's is computed to enable the depot to resupply the intermediate level when SRU's are sent to depot for repair.

### **3. Sensitivity Analysis**

The model can perform four types of sensitivity analysis. They are swept, extremes only, wholesale and pareto. In swept, the user selects a range (for example, MTBF of 200 to 600 hours) and the program sweeps through the range one LRU or SRU at a time. When using extremes only, the sensitivity analysis is done only on the upper and lower extremes of the range chosen. In wholesale changes analysis, all changes for a given factor are made at the same time. This is usually used if the total system cost is of interest vice repair policy. In Pareto, only the highest cost or the lowest MTBF items are analyzed instead of analyzing all LRUs or SRUs.

### **4. Model Outputs**

There are eleven types of output presented by the model. "They contain data input, intermediate results, supplementary information, the optimal solution, and sensitivity analysis." (ASC/ALTD, 1995) All input record are printed in the output. The general information output report contains weapon system data, maintenance system data, supply system data, output options, and wholesale factors. Support Equipment and pareto change

factors are reported together. Repair Level Decision Details contain LRU, LRU failure mode, and SRU data. Support Equipment to LRU/SRU Relationships is also an output report. The user of the model can designate which output options he wants to receive. However, "the reports that are not optional are the Repair Level Decisions, Summary Statistics, Summary Sensitivity Analysis Results, and Detailed Sensitivity Analysis Results." (ASC/ALTD, 1995)

## **C. U.S. NAVY: LEVEL OF REPAIR ANALYSIS (LORA)**

### **1. Background**

LORA is used to ensure the optimum economic use of resources. Its purpose is to determine the least-cost feasible repair or discard decision with regard to corrective maintenance and to influence the design of the equipment toward that repair level decision. In NAVAIR this analysis can be economic, noneconomic or preempting factors such as safety or security.

### **2. Model Overview**

- Model applies only to corrective maintenance. "Preventive maintenance requirement are developed through the Reliability-Centered Maintenance (RCM) process." (NAVSEA, 1990)
- Model purpose is to be done early in the development process "so that design can be influenced to allow for repairs to be performed at the lowest possible maintenance level." (NAVSEA, 1990)
- Model considers three levels of maintenance. They are organizational (O), intermediate (I), and depot (D).
- LORA starts at the system level and then is conducted on the item level.
- Final phase analysis is conducted to determine the actual level of repair.

### **3. Final Phase Analysis**

This is the last step in determining the optimum repair level. This phase consists five areas. They are item level screen, O-level evaluation, I-level evaluation, D-level evaluation, cost analysis, and analysis of LORA results.

In item level screening, each item in the system is screened. "The screening process evaluates the item by assessing whether: (1) the item is a consumable, (2) the item has such a low cost that an analysis is not warranted, (3) pre-empting factors apply, and (4) remove/replace decisions pre-empt maintenance at certain levels." (NAVSEA, 1990) This process ensures that only the items that warrant will receive a full evaluation.

The O-level, I-level, and D-level evaluation are basically the same. The NAVSEA manual's premise is "to drive repair authorization at the Fleet level (O or I-level), provided that all the resources needed to perform the repair are available (existing and in-place) at that level, to maximize the achievement of readiness objectives and to minimize the supply support pipeline. If the Fleet does not have the resources, cost analysis is performed to determine the lowest maintenance level that should repair the item." (NAVSEA, 1990)

The performance of cost analysis is of significant importance. If the capability for repair does not exist at any level, the cost analysis is performed to determine the least cost alternative. Basically the analyst sums all annual cost for the repair of an item and compares the cost from each level of maintenance. There exists a degree of error based on the level of confidence associated with each variable. The analyst then selects the least cost alternative and determines the discard threshold. The discard threshold occurs when the unit repair cost is greater than the item cost. Then it is not economically effective to repair the item. After this step then analysis of the LORA results as a whole must be performed. This must be done because although one item's repair level may have a minimal impact on supply support, the cumulative result of many items could have a significant impact on the supply and support needed.



### **III. DMSO AND THE NAVY**

In this section of the thesis we examine the Defense Modeling and Simulation Office (DMSO) and its interaction with the Navy. We research how DMSO came into being and its purpose. We also explore how the Navy's modeling and simulation office evolved into its current place in the organization of the Navy. With computer modeling and simulation use increasing dramatically in logistics, it is important for a navy logistician to understand the organizational structure, relationships, and some history which may continue to influence policy and attitudes.

#### **A. THE DEFENSE MODELING AND SIMULATION OFFICE (DMSO)**

On June 21, 1991 the Defense Modeling and Simulation Office (DMSO) was established by the Undersecretary of Defense for Acquisition. DMSO's purpose was to "serve as the executive secretariat for the Executive Council on Modeling and Simulation (EXCIMS) and to provide a full-time focal point for information concerning DoD modeling and simulation (M&S) activities." DMSO is a joint staff that reports to the Director, Defense Research and Engineering (DDR&E), Office of the Undersecretary of Defense for Acquisition and Technology(USD(A&T)). (DMSO, 1995)

DMSO's purpose can be fully understood by reading of the foreward in the DoD M&S Master Plan. The foreward is

The DoD Modeling and Simulation Master Plan is authorized by DoD Directive 5000.59, "DoD Modeling and Simulation (M&S) Management," January 4, 1994. The DoD M&S policies, organizational responsibilities, and management procedures are outlined in DoD Directive 5000.59. This Plan is the Department of Defense's first step in directing, organizing, and concentrating its M&S capabilities and efforts on resolving commonly shared problems. The immense breadth and scope of DoD M&S uses, combined with the relative immaturity of many segments of the larger DoD M&S community and its technology, ensure this first iteration is incomplete. Over time, with the active participation and support of the DoD M&S community, this plan will mature to address the full range of issues confronting DoD M&S. Many policy and technical issues may not be identified or resolved; however, this plan, with the management framework and policies established in DoD Directive 5000.59, provides a means to

achieve common technical and policy consensus. This plan is intended to be dynamic and flexible, a living document that will evolve as technology matures and consensus develops on policy and programmatic issues. (DMSO, 1995)

DoD management of modeling and simulation is governed by DoD directive 5000.59. This directive details the responsibilities of DMSO and EXCIMS and describes how DoD will manage modeling and simulation. It is interesting to note that the directive mandates, among many other things, that a DoD M&S Master Plan be developed and a coordinated DoD M&S investment plan be developed. The current version of the DoD M&S Master Plan is available and several functional area plans such as acquisition and DoD investment are still being developed two years after this directive was issued. Additionally, only master plans for the Army and the Marine Corps are present. In essence we are trying to manage modeling and simulation in DoD without having a complete plan from which to work. DMSO basically promulgates guidance and attempts to promote cooperation among all DoD components in order to increase efficiency in the use of modeling and simulation.

In order to keep all services involved DMSO's staff is a joint staff. It is comprised of officers from the United States Air Force (USAF), the United States Army (USA), the United States Navy (USN), and the United States Marine Corps (USMC).

In 1991, DMSO started out with about \$40 million. In 1992 the budget increased to \$75 million. But, this year the pentagon cut the budget for DMSO to about \$52 million. (Holzer, 1996) This is nearly full circle budgeting for this office.

In its first year of existence DMSO began funding computer modeling and simulation. DMSO sent letters out to the individual services requesting proposals for consideration. DMSO funded 16 out of 230 proposals and funded zero at 100%. Additionally, the submitters of proposals were not given any feedback on the reasons of rejection. (McMasters, 1992) The lack of a strong, centralized, modeling and simulations



management structure throughout DoD and a constant budget crunch means an uncertain future also.

## **B. NAVY INTERACTION WITH DMSO**

The Navy started out with an organization called Team Mike. Team Mike screened Navy proposals and forwarded them to DMSO for consideration. Team Mike started when the Director of ASW and Ocean Surveillance Programs was the Director of Naval Warfare. There were several teams representing functional areas in the Navy. These teams included Alpha-antisubmarine warfare, Charlie-C3, and Mike-modeling. Team Mike's initial concern was finding support for wargaming, enhancing and setting up Fleet Project Team for ENWGS at the War College and TACTRAGRU tool for Battle Group Commander and staff training. (Phillips, 1996)

When the Director of ASW and Ocean Surveillance Programs became the Director of Naval Warfare and later the Deputy Chief of Naval Operations (DCNO) for Naval Warfare, the Director of Tactical Readiness Division reorganized under DCNO, Naval Warfare. The Fleet Readiness Section worked for Director of Tactical Readiness Division. The Fleet Readiness Section was involved in studies at the DoD level. (Phillips, 1996) DMSO then came into being with \$70 million budget for the enhancement of modeling and simulation in DoD and a plan for pilot and demonstration projects. Team Mike became the vehicle for the Fleet Readiness Section to promulgate opportunities to the Navy and screen navy requests for submission to DMSO.

The Fleet Readiness Section transitioned to the Navy Modeling and Simulation Section. As development of SECNAV Instruction 5200.38 began the question of "who owns Navy M&S" was addressed at the three and four star level. It was decided that Support to Operations should own it. (Phillips, 1996) The initial transition from DCNO, Resources, Warfare Requirements and Assessments to Support to Operations was delayed temporarily until the SECNAV instruction was signed. Additionally, the head of the

Assessment and Affordability Branch had departed in the spring and the billet was left vacant. Support to Operations decided to proceed with the transition anyway and the Navy Modeling and Simulation office was placed into Strategic Planning Office. The head was dual hatted as Assistant for Strategic Planning and Director, Navy Modeling and Simulation Management Office. The office's focus was mostly on strategic planning so in mid-summer, "CAPT Jay Kistler was detached from SPAWAR and reported in as Director, Navy Modeling and Simulation Management Office. We were then extracted from the Strategic Planning Office nest and put on our own as the Navy Modeling and Simulation Office." (Phillips, 1996)

In 1994 SECNAV Instruction 5200.38 was issued to give instruction on the management of modeling and simulation within the Department of the Navy. Team Mike was not included in the formal management of modeling and simulation within the Department of the Navy structure because it was determined that too many of the members were traveling too much in order to represent various outlying organizations such as NRAD, Port Hueneme, etc. Functional area managers were established and the use of appropriate representatives replaced Team Mike.

Currently, the Director of Navy Modeling and Simulation is a Navy captain and the deputy is a USMC colonel. These positions rotate. The office establishes policy for Navy modeling and simulation and monitors the enactment of standards throughout the Navy. Its budget is for these purposes only. Funding and management for modeling and simulation comes from functional area managers. For example, DCNO for Training funds and manages training. However, the Marines have a quarterly modeling and simulation working group that represents a wide range of organizations across the Marine Corps. "Fleet representatives have indicated the need for working groups." (Phillips, 1996)

The Navy Modeling and Simulation Office attempts to keep abreast of all the activity between DMSO and the Navy. However, this is difficult due to the formal

structure that is in place. When the Director for Force Structure, Resources and Assessment set up a project office, the Joint Analytic Model Improvement Project, their point of contact is the Assistant DCNO for Resources, Warfare Requirements and Assessments. "Assistant DCNO for Resources, Warfare Requirements and Assessments office kept us informed of their actions." (Phillips, 1996) Another example is the Joint Simulation Systems (JSIMS). JSIMS focuses on training and their point of contact is DCNO for Training. "The member of the JSIMS 'General Officer Steering Group' was designated as an assistant under the DCNO for Training." (Phillips, 1996) The Navy Modeling and Simulation Office is not large enough to keep track of or participate in all Navy interactions with DMSO. The formal structure requires DMSO communicate with the Navy via the Secretary of the Navy (SECNAV) or the Chief of Naval Operations (CNO). "DMSO generally knows that to communicate with the Navy, they need to send us at least an info copy of the material...."(Phillips, 1996) However, most information is gained through informal communication within the modeling and simulation community.

Currently the Navy Modeling and Simulation Office is developing a Baseline Assessment Memorandum, an input into the POM development process, addressing the state of Navy modeling and simulation. "Likely output is that without a strong Fleet/Lab/industry panel and voice, Navy M&S will be a back burner issue and will not thrive." (Phillips, 1996) Working Groups get the ultimate customer in modeling and simulation purchases, the user, more involved and provides the management of the Navy with deckplate information on what is actually happening throughout the fleet.

### **C. SHOULD THE NAVY CHANGE ITS MANAGEMENT OF M&S?**

To answer this question, the Navy should conduct its own internal examination. As to whether an internal examination should be conducted, we believe the Navy should look at what is happening in one of its sister services, the Army. "Critics of the manner in which the Army has invested in modeling and simulation say the service has lacked a

strategy, efficient management, and oversight.” The new Chief of Staff, Gen. Reimer, empowered an office in the Pentagon to focus the Army’s modeling and simulation. This office is the Simulation Strategic Planning Office (SSPO).

The Simulation Strategic Planning Office (SSPO) is in charge of two teams that are “conducting a review of modeling and simulation projects, their funding and strategies, with an eye toward identifying efficiencies.” One of the duties of the teams is to define “what ‘models’ and ‘simulations’ are.” The teams are also “collecting a baseline of information about exactly what projects are taking place where; and determining the proponents for these projects.” (Sherman, 1995)

The Army feels it is not getting a return on its modeling and simulation investment and is conducting an internal review and reorganization before it is ordered to do so. Although SSPO is a new office, it has an opportunity to provide a tremendous impact to the future of modeling and simulation in the Army. “The new office is to develop and establish M&S standards, assess M&S management across the service, and provide centralized strategic management with a decentralized execution of the service M&S master plan.” (Sherman, 1995)

We believe the answer to the question of change is possibly. The answer to the question of internal examination and assessment is definitely yes. The Navy should follow the Army’s lead and take a detailed look into where modeling and simulation dollars are being spent.

## **IV. KEY NAVY SIMULATIONS ISSUES**

### **A. OVERVIEW**

There are two problems with the use of computer models and simulations. The first is, how to properly use models and simulations in the many applicable areas to reduce cost, increase quality, and reduce time and risk in fielding new weapon systems. Second is how to buy models more efficiently and effectively by using modular design and reusing software. (Kistler, 1996) The proper solutions to these problems will dramatically increase the effective use of computer models and simulations within the Department of the Navy and the Department of Defense.

Computer models and simulations do not determine missions. The mission comes first, then models and simulations. Matching computer models and simulations with missions is an important potential asset for decision makers. Well-designed computer models and simulations can help decision makers understand risks and uncertainties and thus have a more complete understanding of the problem they are facing. Determining the payoff of this use of modeling and simulation is next to impossible. This is because the determination of a utility function for the use of modeling and simulation is almost impossible.

### **B. USE OF COMPUTER AIDED DESIGN (CAD)**

Probably the biggest ticket item in computer models and simulations right now is CAD, because CAD has the ability to influence every major acquisition DoD makes from now on. It is not without some problems however. In this section we will address the use of CAD in the new attack submarine and the surface combatant of the twenty-first century (SC-21).

#### **1. The New Attack Submarine**

The attack submarine program used intergraf CAD2. Electric Boat Corporation detailed Catia to develop a CAD like the one used for the Boeing 777. The problem from

the beginning was inoperability between various CAD systems and various shipyards with different CAD systems and non-transferable files. (Henry, 1996) Also, CAD is a huge initial investment for a program. Because of the CAD, there are more questions, so even more time is spent on feasibility studies. For example, there were about 80 feasibility studies for the Seawolf submarine. With the new attack submarine there have been over 100 in-house feasibility studies and dozens more done by agencies outside NAVSEA already.

Prior to Electric Boat getting the contract the Navy was using the Intergraf CAD system in the new attack submarine. Intergraf is a full blown geometric associative model that is designed to be run from a database using a network server. The Navy bought this to yield a product model. (Burkeen, 1996) Each ship must have its own product model (3-D physical model). Intergraf has 4 core products that are layered on top of one another. They are an engineering model system (EMS), an vehicle design system (VDS), a structural model (IS) and a systems model (IR). The systems model is piping, electrical, etc. The result is a non-integrated, complex system of software.

There are two ways to design a software system. The first is top-down. This involves big picture software design. The second approach is bottom-up. This approach involves designing the little pieces which are uncoordinated and then integrating the entire system. Intergraf is a bottom-up approach. The advantage is practically all the software is commercial-off-the-shelf. The disadvantage is that the result was software that was bug-ridden and difficult to use. (Burkeen, 1996) Corruption on a model from a CAD and associative CAD system will propagate. This is because associative models are like graphic programs. An example would be machine parts. Different pieces of geometry have dependency or parents on which to build. Then functions similar to macros are run to yield the product.

The next version of CAD comes out and changes some commands and the result is implosion of the model. (Burkeen, 1996) In the early design phase this happened and the result was a fiasco.

The use of CAD in detail became infeasible due to corruption. The corruption source was a combination of several factors. These include the modeler and the complexity of the system, lack of expertise, and the new version of the CAD. The utility of the CAD was questioned due to the short time frame of the benefit because the files were a non-retrieval format and therefore could not be reused. The end result was during early stage design the CAD became merely an information system.

One of the main preventers of progress in all computer aided engineering (CAE) being used effectively in design is no confidential network within the DoD agencies in Crystal City and Washington, D.C. People are performing the tasks manually, literally drawing on pieces of paper. CAD is more important as a communication device. DoD needs a functioning network and a product data manager. Additionally this network needs to be tied into the shipyards. This will be a very expensive investment. But, the current piecemeal fashion of operation leads to enormous waste. The waste is due to the system not being networked. The administrative cost and the cost of software to run stand-alone at NAVSEA is huge. The reason is the entire database must be duplicated at tremendous cost of time and money and risk corruption and then carried space-to-space. Currently the CAD is at Newport News and there is no way for NAVSEA to access it. The system needs to have everyone on a real network database and everyone plugged into it. There should not be isolated access areas like there are currently. (Burkeen, 1996)

Another major area of concern is software development and management. For example, the technical point of contact cannot monitor actions because he cannot test or understand the source code. The reason is he gets a budget of \$375,000 for software development. But, he cannot use one cent to buy hardware or software he needs because it

is forbidden by law. The current laws prevent him from using this money for the purchase of personal computers or operating systems because these items do not fall into the under development category. "Engineers are buying software out of their own pocket to make life easier." Laws and regulations governing expenditures of money do not match the new technological requirements and the procurement of software and hardware is not on pace with the technological development. Sanctions are preventing the procurement of inexpensive alternatives. (Burkeen, 1996)

The management of the Federal acquisition process is highly regulated and IT procurements are subject to the following laws and regulations:

- Brooks Act (P.L. 89-306)
- Warner Amendment (P.L. 99-500)
- Paperwork reduction Act (P.L. 96-511)
- Paperwork reduction Reauthorization Act of 1986 (P.L. 99-500)
- Competition in Contracting Act (P.L. 98-369)
- Computer Security Act of 1987 (P.L. 100-235)
- Privacy Act of 1974 (P.L. 93-579)
- Federal Acquisition Regulation (FAR)
- Federal Information Resources Management Regulation (FIRMR)
- Federal Property Management Regulation (FPMR)
- OMB Circular A-130, Management of Federal Information Resources
- OMB Circular A-76, Policies for Acquiring Commercial or Industrial Products and Services Needed by the Government
- OMB Circular A-109, Major Systems Acquisitions
- Plus any agency specific guidance regarding acquisition and operation of IT resources. (Willis, 1994)

## **2. The Surface Combatant of the Twenty-first Century (SC-21)**

The SC-21 is also using the CAD in its program. In use is a Product Model Enhancement (PME). This graphic CAD system was developed by Intergraf in April 1990 and used heavily in the LPD-17 program. Conceptual improvements were made in the system for use in the SC-21. The CAD is being used to place items on the ship in the design phase.



These items are graphically designed and placed into a data base. During the ship design phase about 20% of the items are modeled in the CAD file and about 80% are in specifications files or other non-graphic files. (Zebrowski, 1996)

The PME control of the product database has been under development for about two years. This data base concept allows the entire ship and all the parts of the ship to be entered into the data base without graphics. As the design progresses the design can be updated. By mid-March this concept will be in full use for the SC-21.

The CAD system that will be used involves three different software items. They are PME, Docmgr2, and metaphase. The system currently uses Oracle which is a relational software. However, the SC-21 program will be switching to Informix because they currently own the license to Informix along with CAD2. Docmgr2 is a commercial document management system produced by Intergraf. It is based on metaphase which is an object oriented management system. Now Oracle is a very robust system with a distributed data base that is designed to be networked. But, there is a logistics problem with security. The SC-21 program will probably get around the lack of secure network problem that is also present in the new attack submarine program. The SC-21 program plan is to piggyback on the modeling and simulation site in NAVSEA since this links to secure sites in other model and simulation centers.

Currently Intergraf is comparing Informix and Oracle. This is to ensure that essential capabilities will not be lost when the program switches software. If the findings of the study indicate that some capabilities that are considered essential will be lost then the SC-21 program will stay with Oracle. (Zebrowski, 1996)

Potential problems with the use of CAD in the design and building of surface ships became evident in the DDG-51 program. There were two different shipyards with two different CAD systems.

With the use of CAD, there is a tendency to do some things on the ship first and then go back to the CAD and try to fix it. (Zebrowski, 1996) In order for CAD to work properly the discipline to use the model must be maintained.

Currently, the CAD can only handle one ship vice a class of ships. In order to use the CAD for a second ship of the class, the data base must be created from the beginning. Phase 2 of the product model enhancer is being designed to handle classes of ships. It is also being designed to share the data amongst the ships of the class. This means to design the second ship of the class the data base will not have to be created from scratch.

Does CAD yield a design faster? The answer to this question is both yes and no. For example, by hand maybe you could do 5 studies per week and now you can do 10 studies per week. This improvement will hopefully allow you to get a better design out of the process. If you reduced the number of people because of computers, then your output will be the same as before computers. CAD still takes time but people ask for more things more often. There is the perception that if it is "done by computer, it's instantaneous." (Zebrowski, 1996)

## **C. JSF (JOINT STRIKE FIGHTER)**

### **1. Background**

Joint Strike Fighter (JSF), previously known as Joint Advanced Strike Technology Program (JAST), is a joint program for the development of a new aircraft. JSF's vision is "A Joint Services Team creating the building blocks for affordable, successful development of the next generation strike weapon systems." The service needs are as follows. For the U.S. Navy, a "first day of war, survivable strike fighter aircraft to complement the F/A-18E/F." The U.S. Air Force needs a "multi-role aircraft (primary A/G) to replace the F-16." Finally, the U.S. Marine Corps needs a "ASTOVL aircraft to replace the AV-8B and F/A-18." The program is concentrating on developing a family of three aircraft.

The goal is to use a common production line to build the most affordable aircraft and to add service unique items to the aircraft. An example of a service unique item is the Navy's aircraft carrier shipboard tailhook. (Hamman, 1995)

## **2. Organization**

JSF is a highly successful joint acquisition program. Its success is directly attributable to its organization. The director of the program is U.S. Air Force and the deputy is U.S. Navy. These positions rotate according to normal personnel rotation plan. This arrangement ensures both principal parties best interest in the program is maintained and ensures teamwork. "The organization functions as integrated product teams." (Hamman, 1995)

## **3. Other JSF Issues**

The JSF program is using an extensive modeling and simulation process that includes virtual environment, prior to flight test. Although this modeling and simulation is on a much smaller scale than the entire Department of the Navy or the Department of Defense its success is due to its organization and management. One office manages and acts as a clearinghouse for all simulations with the program. The money flow is directly traceable from the director down and the exact amount of dollars being spent on computer modeling and simulations is known.

In the area of simulations, there does not appear to be a strong simulations applications program in place. There is an area in the "Modeling Simulation & Analysis Process" for JSF that is called "constructive simulation". However, when examining this area in detail it looks as if this is the use of different models to evaluate campaign, mission, etc. and not a graphical simulation program. There are several areas in which a graphical simulation would be beneficial to the decision makers. One of these would be a simulation of the "common production line." (Hamman 1995)

We did note, with some interest that while JSF is a joint program, the analysis of the Services logistic data is being kept separate. "So analysis on USAF comparative data would use NRLA and USN data would use LORA. We have not reached the point where production or production-like designs are being looked at in detail by government analysts." (Hamman, 1996) NAVAIR has taken the lead in developing the Joint Aviation Model (JAM) for use in the JSF program. JAM will be discussed in detail in Chapter V of this thesis.

#### **D. CONTINUOUS ACQUISITION AND LIFECYCLE SUPPORT (CALS)**

"Continuous Acquisition and Lifecycle Support (CALS, also known as Commerce At Light Speed) is a strategy to accelerate the transition from paper-intensive non-integrated product development design and manufacturing, and support processes to a highly automated, integrated mode of operation by developing (1) standards for data storage and exchange; and (2) automated systems to store, manage, and distribute this information to many and varied users across an enterprise." (CALS, 1996) CALS was originally developed in 1984 and was known as Computer-Aided Logistic Support. The Deputy Secretary of Defense issued two memorandums "to establish plans to acquire, process, and use technical information in digital form." (CALS, 1996) In 1987, the name was changed to Computer-Aided Acquisition and Logistic Support. "This brought in functions and disciplines associated with contracting, work breakdown structures, design specifications, drawing preparation and release, testability, produce-ability, reliability and maintainability." (CALS, 1996) Later, CALS name was change to its current form and more government agencies became involved. CALS is now starting to attract European and Pacific Rim countries.

Why did CALS start? The answer to this question is money. DoD managed many of its weapons systems and acquisitions manually and on paper. "DoD spends more than \$10 billion annually to store, maintain, and revise the technical data needed to support

weapon systems.” For example, “the technical manuals needed to perform maintenance and repair on a Navy destroyer weigh 23.5 tons. Overall, the Navy maintains more than 237 million drawings and more than 15 million technical manuals, at an annual cost of over \$4 billion.” The other branches over service spend similar amounts of money on these same types of items. (CALS, 1996)

“The objectives of CALS are to improve timeliness, reduce cost and improve the quality of products and their supporting technical data.” The accomplishment of these objectives is essential for the military and the government in this era of declining budgets.

The immediate goal of CALS is to provide basic capabilities for the digital transfer of engineering drawings, technical and training manuals and logistic support products. The longer term goal is the development of integrated databases that represent all current technical data about a product through each stage of its life cycle. It is through this long term goal of shared databases that integrated product development (concurrent engineering) and other parallel acquisition processes can take place. (CALS, 1996)

CALS will achieve these objectives by using standards. “CALS incorporates three types of standards.” They are functional, technical interchange, and data standards. Functional standards refer to “ data creation and the content and format of data products.” Technical interchange standards are standards “which control the medium and process of exchanging data between sending and receiving systems.” Data standards “govern information sharing and data exchange in an open system environment. CALS philosophy is that to function competitively, management must realize that national and international standards are the conduits for carrying U.S. Products, services, and technologies into the global marketplace. (CALS, 1996)

In order for CALS to accomplish the aforementioned goals and objectives STEP must be developed and implemented. “STEP is being designed to give a complete, unambiguous, computer interpretable representation of a product throughout its lifecycle.” This is a progression from sharing data to multiple user interface. In this system many users, organizations, producers and consumers will be able to access life cycle data on a

product. "Data access delivery and distribution will be through Contractor Integrated Technical Information Services (CITIS). CITIS is the vehicle to provide consumers with access to information associated with life cycle product development." This information system will control access to data and ensure that users can access only what they are authorized to access. (CALS, 1996)

As previously stated, a long term goal of CALS is integrated product development or concurrent engineering. STEP is the essential element to achieving this goal.

Concurrent Engineering is the systematic approach to creating a product considering all lifecycle elements and in doing so, simultaneously defining the product, manufacturing process, and support. Concurrent Engineering applied to manufacturing is a critical link in the enterprise and life cycle of any product. CALS is the integration of information whereas Concurrent Engineering is the integration of processes. This combination is necessary to achieve the ultimate goal of Enterprise Integration. (CALS, 1996)

CALS has become a key logistics ingredient in several Navy programs. One of these programs is the Seawolf attack submarine program . Newport News Shipbuilding is the lead design yard for the Seawolf. "To stay competitive, CALS principles and concepts are imbedded in designing and building major weapon systems. This fact has been most apparent in the design of the Seawolf, the first submarine totally designed using computers." The development and implementation of STEP will be the last item needed to make CALS complete. "The technology and standards for exchanging a fully attributed, three-dimensional solid model are not yet available-for that we must have STEP." (Burke, 1992) In the meantime, CALS principles and concepts are being used and probably will remain in place for long into the future.

## **V. JOINT SIMULATIONS**

### **A. JAM (JOINT AVIATION MODEL) FOR LORA**

In this section of the thesis, we take a brief overview of JAM. JAM was developed because there did not exist a tool to provide a Joint NAVAIR/Air Force acquisition program repair/discard decisions. "JAM is being produced to provide a single (software application) level of repair analysis model to accommodate the Navy, the Air Force, and Joint program needs. A Memorandum of Understanding between NAVAIR and Air Force (Jan 93) agreed to pursue this joint project. The Air Force provided \$150K from the V-22 program and NAVAIR provided \$37K (and agreed to provide additional funding as required.)" (Hamman, 1996) The information contained in this section was obtained from the paper "The Genesis of JAM for LORA" by Stephen H. Doragh.

#### **1. Background**

The idea for a joint Level of Repair Analysis (LORA) program initially began at the V-22 "Osprey" program office at Naval Air Systems Command (NAVAIRSYSCOM) in 1993. "Joint acquisition programs are those that involve more than one service (Army, Navy, Marine Corps, United States Air Force (USAF), and occasionally, Coast Guard, & Federal Aviation Administration (FAA)) in the development and acquisition of a weapons system by the government. In the case of the V-22, all three military services were involved when the acquisition program began." (Doragh, 1995) Joint programs present a whole new set of problems for the program. Each service has its own LORA models for its own acquisitions. Each LORA model is biased toward the maintenance philosophy and policies of the individual service. "For example, NAVAIR's model provides for aircraft to be stationed on aircraft carriers, the Army's model has five repair levels, and the USAF's model is designed to be run by end item. However, in light of the smaller defense budgets projected for the future, it is assured that 'joint' programs will become more and more common." (Doragh, 1995)

The peculiarities of each services' models create a quandary for the program office of a 'joint' program. Do they use one service's LORA model for all repair level studies and accept that the selected model will not precisely fit all of the services' maintenance scenarios? Or do they allow each service to use their own model for the end items they will operate, e.g., "Enter the Navy's aircraft in a navy model and enter the USAF's aircraft in the Air Force's model?" The problem with the latter approach is that any advantages gained by having combined LORA runs and optimizing the support equipment use for all Intermediate Maintenance Activity (IMA) sites and depots are lost. (Doragh, 1995)

This led the Osprey program office to begin pursuing a joint LORA model. "They realized: (1) that NAVAIR and USAF have very similar maintenance philosophies for corrective repair of aircraft and its equipment; (2) that one LORA model could be developed for use by both services; (3) that each service also had its own, aging LORA model that required updating; and (4) both models used old software techniques that did not take advantage of the capabilities of modern personal computers." (Doragh, 1995) The result of this pursuit is JAM for LORA.

## **2. LORA/NRLA Similarities**

- "Both models calculate the total operating hours of all operating end items at all operating sites to determine the total number of failures for the items under analysis."
- "The USAF's maintenance planning policy has a greater bias towards two level maintenance (Organizational Level to the Depot) than the Navy's policy. However, both models require the user to enter data as if the items under analysis were going to be repaired using a three level maintenance concept (Organization to Intermediate to Depot). The models then test both the two level concept and the three level concept to determine the maintenance plan with the lowest cost for maintenance over the life cycle of the system being studied." (Doragh, 1995)



- "Both models determine the cost "impact" of a maintenance concept on existing maintenance sites. The models assume that the sites already exist with hangars, runways, common support equipment, and a standard manpower complement. They measure what the costs of adding the items under analysis to these sites will be in various combinations and compare them to each other."
- Both models lack a on-line help feature.
- Both models were designed for use in a non-Windows environment.
- Both models were designed and produced before LSAR Mil-Std's-1388.2A or 1388.2B were developed so they cannot take full advantage of the LSAR database.
- Both models were written in older computer languages (NRLA- FORTRAN; LORA- C+).
- Like all software programs, both models require updating or improvement but neither had a steady funding source for this purpose.
- "Both models assign the "costs of support equipment" to the LORA candidates that use the support equipment before the optimization is begun." The way the models assign the costs vary slightly. However, this is a problem for both models.

The fundamental problem with these methods of optimizing LORA data is, the models are attempting to determine the support equipment cost for each item at each site before the repair level has been determined. When using these methods, the model cannot always know how many items are going to be repaired at a site and cannot determine how many hours per month a piece of support equipment is used. So, the model cannot always know how many pieces of support equipment need to be purchased for each site or how to allocate the costs of the support equipment to the items at each site. (Doragh, 1995)

### 3. JAM Algorithm

In setting up JAM for LORA, the team realized the flaws in LORA and NRLA. They realized that those optimization models "did not, and could not, always return the best solution for all items and support equipment." (Doragh, 1995) There are basically two

options for the optimization routine. "What we discovered was that we had two choices: (1) perform an analysis on every possible alternative, called an 'exhaustive' search; or (2) use a new optimization routine that mimic Charles Darwin's theory of evolution or 'natural selection' called 'Genetic algorithms.'" (Doragh, 1995)

An exhaustive search was determined to be unfeasible. The total number of possible maintenance plans was found to be equal to the number of repair levels raised to the power of the number of items under consideration. Each service defined what they considered a valid maintenance plan. This total number includes plans that would be considered invalid.

The two constraints that any valid maintenance plan must adhere to are: (1) A lower indenture level assembly must be repaired at the same site level or higher site level as its next higher indenture level assembly. When running LORA's the lowest site level is the 'squadron' or 'organizational' level, the next highest site level is the 'depot' (commercial or organic), and the highest repair decision is 'discard'. (2) All lower indenture level assemblies of a discarded candidate are discarded with that item; that is, no analysis is performed for those lower indenture level discarded items. (Doragh, 1995)

The reason that the exhaustive method was abandoned was the computation time. For example, "suppose an input file has three levels (IMA, depot, & discard) and 15 items, the total number of alternatives is 14,348,907." If you eliminated half of the alternatives due to violation of the valid maintenance plan constraints, and assumed only 30 seconds to complete the computations for each iteration of the model, "it would take about 60,000 hours (or 2491 days or 6.8 years) to finish all of these runs and find the optimal solution." (Doragh, 1995)

Thus the "Genetic Algorithm" (GA) was selected as the best alternative to pursue. The algorithm basically uses the rules of nature to find the best solution. It searches a "state space" where all possible solutions are located. Then the algorithm combines "parts of the most successful solutions, to create more successful solutions using a process called 'mating'". (Doragh, 1995) The cost module is separate in JAM. The GA creates

maintenance alternatives to be evaluated by the cost module. "The cost of the alternative is returned to the genetic algorithm and then the genetic algorithm determines the relative quality of the answer." (Doragh, 1995) It avoids the support equipment problem experienced by the other models by giving the repair level for every item to the cost module by the GA. "JAM for LORA is 'given' and then calculates exactly which pieces of support equipment are required for every site and how many of each support equipment are required for each site, for every iteration of the Cost Module." (Doragh, 1995)

#### **4. JAM Characteristics**

- It can be used for joint Navy/USAF programs, Navy only programs, or USAF only programs.
- It operates in the Windows environment.
- It is user friendly.
- It has on-line help.
- It continuously updates its database as the user enters data.
- It is written in a database computer language (Foxpro).
- It "calculates the total number of operating hours per month at each site for each aircraft type (or end item)." (Doragh, 1995) This allows the user to compute "site operating hours."
- It can show an "Item Efficiency Index". "This is an output report that shows the relative impact of changing inputs that affect an item's 'availability'".  
(Doragh, 1995)
- It can run separate "systems" in the same model run.

#### **5. JAM Reports**

JAM for LORA has the ability to generate the following reports:

- Item repair dispositions
- Item disposition (detail/summary)

- Life cycle cost (detail/summary/summary by site)
- Support equipment
- Inventory (detail/summary)
- Optimization graph/list
- Standard summary
- Top ten summary
- Sensitivity analysis (Doragh, 1995)

## **6. Engine LORA Model (ELM)**

Also under development is ELM. This model is very similar to JAM except it is tailored for gas turbine engines. It will also have the ability to be used for Navy only, USAF only, or joint USAF/Navy engine programs.

## **B. JOINT MATH MODELS**

In this section, we will discuss briefly several joint math models being developed at the Joint Logistics Systems Center (JLSC). The purpose of these projects is to look at standardizing models used for setting wholesale and retail inventory levels. It is the intention of this section to give a logistician some insight into the tools currently being developed.

### **1. Statistical Demand Forecasting (SDF)**

This model's purpose is to forecast the mean and variance of the net demand during the procurement leadtime and the demand during the repair turn-around-time for use in requirements determination. "This model forecasts the means and variances (where appropriate) for the following variables: demand, regeneration, final recovery rate, unserviceable returns, unserviceable return rates, serviceable return rates, nonrecurring demand rates, administrative leadtime, production leadtime, procurement leadtime, retrograde time, administrative repair time, depot maintenance time, and depot repair cycle time." When using the model, different forecasting items are available for different items.

The model can be applied to consumable and repairable items, program and nonprogram related items, and family and bachelor items.

"The model uses Statistical Process Control (SPC) techniques to identify when a change in the demand pattern is statistically significant and requires an update (or change) to the forecast." It can also provide for the identification, exclusion, or modification prior to use, of outlier observations. The model has the ability to identify trends and adjust the forecast accordingly. "The SDF consists of two parts: a 'black box' subroutine accessed by Requirements Control System (RCS) and Central Secondary Item Stratification (CSIS); and, a PC Exception Tool, used to review/change/simulate/re-forecast items." (Moore, 1996)

## **2. Economic Order Quantity/Variable Safety Level (EOQ/VSL)**

The EOQ/VSL math model is used for computing inventory levels for secondary items. This model does the mathematical calculations and processes required for this computation. "The model acts as a 'black box' accessed, as required, by DoD systems, including the Requirements Computation System (RCS), Simulation Recomputation Tool (SRT), Central Secondary Item Stratification (CSIS), and Computation and Research Evaluation System/Supply Performance Analyzer (CARES/SPA)." In the model consideration can be given to both family and nonfamily items.

The system basically provides output based on whatever input it is given. "The accessing system provides the input and parameter data and the model returns the output data to the accessing system." The model performs all necessary mathematical computations to determine when and how much material to buy and repair, "as required by RCS, SRT, CSIS, and CARES/SPA." The model will compute order and repair quantities and reorder and repair levels. It can compute for consumable, repairable, family and nonfamily items. "Necessary preliminary calculations (initial values and constraints and special case establishment and follow-on calculations (backorder, final quantities,

performance projections, and family prorating) are also performed by this model.” (Moore, 1996)

### **3. Computational And Research Evaluation System/Supply Performance Analyzer (CARES/SPA)**

CARES/SPA provides the information necessary to set parameters used in the RCS and CSIS. It is a stand alone point-in-time simulation system. “ CARES/SPA provides and experimental tool to evaluate proposed inventory methods and models and to determine shortage cost values.” The EOQ/VSL “black box is the common model used in the CARES/SPA, RCS, CSIS, and the Simulation Recomputation Tool (SRT).”

The CARES/SPA model may be used on a sample grouping (e.g., “universe of items with similar characteristics) using one of the four different target types. The types are fill rate, dollar value safety level, average wait, and a chosen lambda value. When using the first three types, the model searches for a lambda that will achieve the specified target level. “The fourth option evaluates certain lambda values to determine the impact on measures such as fill rate, average wait, inventory investment, and cost and number of first year buys.” CARES/SPA has a Multi-Link capability. The user of the program can select a target either by National Stock Number (NSN) or NSN group. “For certain user-specified items, Multi-Link provides a multi-echelon computation to determine the performance target that the wholesale echelon should provide.” It should be noted that all outputs provided by CARES/SPA for non Multi-Link items are also provided for Multi-Link items. (Moore, 1996)

### **4. Readiness-Based Sparing (RBS)**

In the world of computer models, new models are being developed constantly for application. At JLSC, another joint model being developed is RBS. Although very few details are available on RBS, it serves as an example on the constant growth in the field of math models. JLSC is developing “retail readiness-based sparing (RBS) models which are

used to determine secondary item requirements for retail (user) sites in a manner which provide the most readiness per dollar of inventory investment.”(Moore, 1996)

### **C. JOINT SIMULATION SYSTEMS (JSIMS)**

In this section we will look at another Joint simulation. While not directly a logistic model or simulation, it provides some insight into potential problems that are faced when conducting a Joint program. Even though the future of simulations and models is joint, they are under constant scrutiny and must be managed carefully.

“The General Accounting Office (GAO) says the Defense Department’s effort to develop a Joint Simulation System is well behind schedule and still lacking a consistent focus, which auditors say could allow DoD to pursue unnecessary upgrades to the current system and let services develop programs that may duplicate the capabilities of JSIMS.” (Dupont, 1995) The GAO is under the opinion that “the JSIMS program ‘has not progressed beyond the conceptual stage since a memorandum of agreement was signed in June 1994.’” (Dupont, 1995) It was intended for JSIMS to replace the Army’s current Aggregate Simulation Protocol (ALSP), which is currently managed by the Army’s Simulation, Training and Instrumentation Command. (Dupont, 1995)

The Joint Staff and the individual services are in disagreement “about the definition of JSIMS and a plan of action”(Dupont, 1995). Meanwhile the Undersecretary of Defense for Acquisition and Technology has chosen not to get involved but rather to let the differences be solved over time.

‘Further’, the report continues, ‘the estimated \$416 million in funding needed to develop JSIMS will be dependent upon agreement by multiple sources- the service and other agencies.’ In addition, DOD is ‘uncertain’ how much it will spend to improve ALSP confederation before JSIMS is available. ‘This uncertainty raises questions as to whether DoD is making cost-effective decisions.’ (Dupont, 1995)

In the GAO report, \$40 million was determined to planning for improving ALSP through fiscal year 1999. It is estimated that many of the improvements to ALSP will be

finished at approximately the same time that it is scheduled to be replaced by JSIMS. “The longer it takes to make JSIMS operational, the more money DoD is likely to spend on a system that will be ultimately discarded.’ In the meantime, GAO states, ‘the services are already developing their next generation of training models without a clear vision of their relationship to JSIMS,’ which could lead to duplicate costs and capabilities.” (Dupont, 1995) DoD only partially concurred with this GAO report.

#### **D. GENERAL-PURPOSE SIMULATION LANGUAGES**

Simulation languages have increased in popularity. The use of simulation languages is necessary for process analysis improvement. There are several simulation languages available. These include Simscript, Modsim, GPSS, and Arena. We have chosen Arena as an example of a simulation language.

It is evident that the Navy has many specialized, high level models and programs in place. Each of these models and programs provide valuable information for logisticians. However, there exists a necessity for process simulation using animation. Process simulation using animation adds a key element to effective logistics planning and management. That element is communication.

DoD no longer has the luxury of large budgets. We cannot afford to spend money on something unless we are reasonably sure of its potential success. Simulation using animation is necessary for “reengineering” the way we do business. It provides a medium for engineers and analysts to effectively communicate plans and proposals to the decision makers. The animation portion allows these decision makers to actually view the impact of a logistics proposal. For example, the decision maker could see the queue growing at an intermediate maintenance facility without having to read through reams and reams of numerical and statistical data output.

One of the most flexible, powerful, and easy-to-use simulation animation programs is Arena developed by Systems Modeling Corporation. Arena can be applied to any



logistics situation and is very effective in representing through animation the process being simulated. Prior to releasing Windows 95, Microsoft used Arena to "determine the effect of the higher volume of customer support calls." The result was customers waiting less than two minutes to receive assistance. (Ferguson, 1996)

Arena is "a comprehensive system that addresses all phases of a simulation project from input data analysis to the analysis of simulation output data." Systems Modeling Corporation designed Arena to build on the capabilities of Siman and Cinema, two of their earlier products. Arena allows a user to easily and quickly model and simulate using animation. This is due to the fact that Arena uses drag-and-drop and windows that allow the user to fill in the blank. However, "a professional user can actually build his or her own simulation system by combining Siman and Arena constructs into modules for the end-user." (Hammann, 1995)

Some of Arena's applications are manufacturing, logistics, transportation, warehousing, and process. (Ferguson, 1996) However, Arena can be tailored to any specific application area. Arena could be tailored to any logistics area. It could be tailored to simulate a ship refueling, supply offload, or an aviation maintenance plan, just to name a few.

As stated earlier, Arena could be tailored to fit any area of logistics. In this thesis we have examined several weapons programs that are ongoing. Arena is a powerful communication tool that could yield immediate results to the program managers. Arena's ability to simulate using animation would allow these program managers to better communicate the logistical details of their program to the decision makers in the Navy and DoD.

One example of the use of Arena would be in the JSF program. Arena could be used to simulate, using animation, the operation of the common production line. This would allow the decision makers to view the planned flow of parts and equipment on the

line. The workload of each planned station of the production line could be viewed. Arena would also allow the decision makers to view the output of the three aircraft (USMC, USAF, USN) of the family of aircraft. The animation would communicate this production line plan more effectively than any other means available.

Additionally, Arena would allow the incorporation of the level-of-repair analysis programs findings into an animation of the repair plan for the JSF. Arena could model the repair plan recommended by NRLA, LORA, and JAM. A visual representation of the maintenance plan is valuable for both the logistician and the decision maker. By being able to see the projected maintenance workload, the logistician for the program could quickly identify potential problem areas before the maintenance plan is adopted. Arena would also enable the decision maker to witness the plan "in operation" well before the maintenance plan is adopted and implemented. This will ultimately save time, money and increase the quality of logistic support for the program.

## **VI. SUMMARY, CONCLUSIONS, AND RECOMMENDATIONS**

### **A. SUMMARY**

As Defense budgets continue to decline, computer modeling and simulation use will rise. Computer modeling and simulation is a cost effective way to conduct analysis and influence program designs toward the most effective and economical design from a logistic perspective. While this thesis provides a Navy logistician with some insight into modeling and simulations, there are changes occurring everyday. Technology continues to advance at a rapid pace and improvement in pc technology allow a logistician to perform analysis on his personal PC that would have previously required mainframe computers. It is important for the Navy logistician to stay informed about modeling and simulation developments especially with the move towards off-the-shelf technology uses. It is especially important for the Navy logistician to get involved early in the development of a system or program and use computer modeling and simulation assets to influence design from the very beginning. This will result in not only the most economical system design but also the most supportable design over the long term.

### **B. CONCLUSIONS**

- There are many specialized computer models and programs in DoN but there exists a necessity for process simulation using animation.

In DoN, we do not take advantage of process simulation. We have many specialized computer models and programs, some of which have been discussed in this thesis. These include LORA, JAM, and ELM. While these programs provide excellent information, they are not process simulations. Process simulations will provide an excellent communication and evaluation and analysis tool for a logistician.

- The ultimate user of computer modeling and simulations is not being involved in the acquisition decisions resulting in purchases being made of incorrect hardware or software.

The Department of Defense has a golden opportunity to set up a simplified management structure right now. The FY96 DoD Authorization Act has removed some cumbersome legislation in the area of information technology. The main highlight is the repeal of the Brook's Act. However, if we in DoD do not show Congress that we can manage ourselves in this arena, legislation similar and possibly more restrictive than the Brook's Act will be put in place. User involvement in the process of ADP acquisition is missing. Also, users are not educated in the process and there is a "user and buyer disconnect". (Stone, 1996)

- The Navy modeling and simulation office is unable to effectively manage computer modeling and simulation within the Department of the Navy due to the organizational structure of computer modeling and simulation management in the Department of the Navy.

Computer modeling and simulation is being used widely in the Department of Defense and the Department of the Navy. However, determining the payoff is very difficult because of the bureaucratic management structure. We must learn to manage computer modeling and simulation more effectively if it is going to pay the dividends we need it to in the future.

- Simulations and models must lean toward the ability to perform joint functions.

More acquisition programs are joint programs due to the decreasing defense budgets. With decreasing budgets, money is not available to update, correct, and maintain numerous computer models.

### **C. RECOMMENDATIONS**

We recommend that:

- DoN promote the use of process simulation using animation (eg., Arena) for all logistics programs.

While the models and simulations we currently have provide essential information, they are also very specialized. The information then must be provided to the decision maker for the program. Process simulation using animation provides an excellent tool for communicating

a logistics plan to the decision maker. Communication is the key. Animation provides a concise way to communicate a logistics plan and also allows for sensitivity analysis. The ease of use of process simulations such as Arena is an additional plus.

- Reorganize the management structure of computer modeling and simulations.

Move the Navy Modeling and Simulation Office to the Secretary of the Navy level, specifically the Assistant Secretary of the Navy for Research, Development and Acquisition Office, in order to provide more influence, visibility, and say in budgetary matters. Direct that the Navy modeling and simulation office define what will be considered a "model" and what will be considered a "simulation". Additionally, DoN direct that the Navy Modeling and Simulation Office control the funding for computer modeling and simulations within DoN and all functional area managers will report to the office on modeling and simulation matters and receive their funding for modeling and simulation from the office.

- The Navy Modeling and Simulation Office reestablish Team Mike, using video teleconferencing if necessary to reduce travel expenses.

This will get the users involved in the process and educate them. Additionally, this will ensure that the leaders and managers of Navy modeling and simulation are hearing unfiltered feedback from the users in the fleet.

- DoN conduct a thorough study of the current ADP acquisition laws and regulations and influence the simplification and elimination of them where necessary to keep up with the fast-paced changes in technology.

In some cases, rules and regulations prevent the purchase of necessary computer hardware or software. In other cases, these same rules and regulations result in the purchase of more expensive hardware or software because purchase of the less expensive items is disallowed. Many of these wastes of money could be eliminated through the use of common sense. Rules and regulations that no longer make sense or have outlived their usefulness given the fast pace of technology should be eliminated.

-Ensure budgeting for computer modeling and simulation within DoN is incorporated within the POM.

If modeling and simulation is to be a high priority for the Navy, it must be in the POM. There is a lot of truth to the belief that if you are not in the POM, you do not exist. Money needs to be available for correcting, updating, modifying, and maintaining our computer models and simulations to ensure we are receiving the best product for our taxpayer dollar.

## APPENDIX. POINTS OF CONTACT

This appendix contains a list of the main points of contact used in this thesis. Their names, phone numbers, and electronic mail address is listed if available. The information contained herein is intended to assist others interested in conducting follow-on research.

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9. JLSC: Mr. Rich Moore, phone: (com) 513-255-3320 (a/v) 785-3320, email: rchmoore@jlsc.wpafb.af.mil
10. LORA (USN): NAVSEALOGCEN, Mr. Russ Jenkins, phone: 717-790-4509, email: russel\_d\_jenkins@nslc.fmso.navy.mil
11. COMPASS (USA): LOGSA, Army LORA Support Office, Mr. Christopher Booth, phone: (a/v) 645-9838, email: cbooth@logsaemh2.army.mil
12. NRLA (USAF): Mr. Rich Lamb, phone: 513-255-2122 ext. 580





## LIST OF REFERENCES

- Alexopoulos, C., and others, *1995 Winter Simulation Conference Proceedings*, p.9, Winter Simulation Conference Board of Directors, Arlington, VA, 1995.
- Brake, F. B., and West, E. A., "CALs at Work in Newport News Shipbuilding", *CALS Journal*, pp. 48-56, Fall 1992.
- CALS Internet Homepage, <http://www.cme.nist.gov/nipde/orgs/cals.html>.
- COMPASS User's Manual, USAMC Logistics Support Activity, Redstone Arsenal, AL, March 1994.
- DMSO Internet Homepage, <http://www.dmsso.mil>.
- Doragh, S. H., *The Genesis of JAM for LORA*, Naval Aviation Maintenance Office, Patuxent River, MD, 12 May 1995.
- Dupont, D. G., "GAO Faults Pentagon's Joint Simulation System Development", Inside the Pentagon's Inside the Army, v.7 no. 45, pp.1, 10-11, 13 Nov 1995.
- ECRC Internet Homepage, <http://www.ecrc.gmu.edu/definition/cals-define.html>.
- Ferguson, G. A., "Buyer's Guide, Simulation Software," *Industrial Engineering Solutions*, pp. 54-63, May 1996.
- Fields, P., MN 3374 course lecture, Naval Postgraduate School, 9 Jan , 1996.
- Goodman, G. W., "Joint Strike Fighter", *Armed Forces Journal International*, Feb 1996.
- Hamman, T. R., CDR, USN, Joint Academic Logistic Management Evaluation (JALME) brief, Naval Postgraduate School, Monterey, CA, 3 Aug 1995.
- Hamman, T. R., JSF Program, electronic mail, 15 Mar 1996.
- Hammann, J. E., and Markovitch, N. A., "Introduction to Arena", *1995 Winter Simulation Conference Proceedings*, p. 519-523, Dec 1995.
- Holzer, R., "Pentagon Cuts DMSO Funds", *Defense News*, v.11 no.1, p.16, 08-14 Jan 1995.
- Innovation Business Services Internet Homepage, <http://fox.nstn.ca/~cottier/overview/CALS/cals.html>.
- Interview between M.Stone, Assistant Professor, Naval Postgraduate School, and author, Monterey, CA, 22 Feb 1996.
- Interview (phone) between R.Zebrowski, NAVSEA O3H12 (arrangements design division for auxillary and amphibious ships), Washington, D.C., and author 14 Feb 1996.

Interview (phone) between M. Henry, NAVSEA O3U (sub design and system engineering), and author, 31 Jan 1996.

Interview (phone) between F. Burkeen, NAVSEA preliminary submarine design, and author, 5 Feb 1996.

Interview (phone) between J. Kistler, Director of Navy Modeling and Simulation, Washington, D.C., and author, 30 Jan 1996.

McMasters. A. W., Trip Report for 31 August to 4 September 1992.

Moore, R., Joint Logistics Systems Center, electronic mail, 5 April 1996.

Naval Sea Systems Command (NAVSEA) *Level of Repair Analysis (LORA) Procedures Manual*, December 1990.

*Network Repair Level Analysis Model User's Guide*, ASC/ALTD, Wright Patterson AFB, OH, June 1995.

Phillips, G., Office of the Director of Navy Modeling and Simulation, N6M1, electronic mail, 31 Jan and 7 Feb 1996.

Piplani, L. K., J. G. Mercer, and R. O. Roop, *Systems Acquisition Manager's Guide for the Use of Models and Simulations*, Defense Systems Management College Press, Fort Belvoir, VA, 1994.

Sherman, J., "New Office takes lead as...", *Inside the Pentagon's Inside the Army*, v.7 no. 45, pp.1, 10-11, 13 Nov 1995.

Willis, C. I., *The Brooks Act, Is It Relevant Today?*, Master's Thesis, Naval Postgraduate School, Monterey, CA, Jun 1994.

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